CHAPTER 13

FIRE MANAGEMENT IN THE SLASH PINE ECOSYSTEM

by

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HISTORICAL PERSPECTIVE

If current lightning frequency is indicative of its past importance, this ignition source was not only capable of, but responsible for, an ecosystem where fire was a driving force. More thunderstorm days occur per year on the southeastern Coastal Plain than anywhere else in the Nation. Over 6,000 cloud-to-ground strikes have been recorded in a single afternoon in South Florida (Maier, Michael, Natl. Hurricane and Exp. Meteorol. Lab., Coral Gables, FL. Per. comm. 1978). Lightning-killed pines are a common sight throughout the slash pine belt. In fact, Komarek (1974a) stated that lightning is a major predator of southern pine. Komarek (1968) counted 174 trees along a 15-mile stretch of road at the Georgia-Florida State line that showed obvious visual damage after passage of a single storm. Hodges and Pickard (1971) reported that lightning-struck pines served as epicenters for 31 percent of the 2,100 tree-group beetle infestations found over a 3-year period on a large ownership in Louisiana.

Snags are often struck by lightning which ignite these dead trees as well as adjacent litter and herbaceous fuel. Lightning fires in the south are usually accompanied by rain showers which extinguish these incipient fires, but enough survive to be a major fire control concern during the summer months. In southeast Georgia, lightning fires cause about 30 percent of all fires (Paul and Waters 1972).

Evidence of a long history of recurrent fire is the vegetation itself. Most of the species endemic to the pine forests of this region are tolerant of fire, and many actually depend upon it for their existence--an evolutionary process that takes considerable time to develop. Without continued disturbance, the majority of these seral species will dominate a particular vegetative strata for a single generation, then rapidly decrease in importance and disappear from the community. This may take only a year or two for many of the herbaceous species or several hundred years in the case of overstory trees such as pine or cypress.

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Historically, the particular species dominating a given site was largely a function of fire periodicity. This periodicity varied by site depending upon such factors as location with respect to natural barriers and proximity to ground water. Even normally wet areas, including their underlying peat or muck soils, occasionally burned, leaving a record of fire occurrence in the form of layers or pockets of ash, sometimes several inches thick (Wade and others 1980). I think the southern pinelands burned over frequently, perhaps the drier, more fire-prone sites as often as every 2 to 3 years. These close-interval fires kept fuels from accumulating to the point where the fire intensity would be sufficient to kill the heat-resistant pines. The thin-barked hardwoods, on the other hand, were generally top-killed and often eliminated by successive fires.

Thus, fire was an integral part of the combination of natural forces that shaped and maintained the dynamic vegetative mosaic that greeted man upon his arrival to the southern Coastal Plain. In fact, because the southern coniferous forest has evolved with and is perpetuated by recurrent fire, it can be designated a fire climax.

Fire as a Process

Fire is neither innately destructive nor constructive, it simply causes change. Whether these changes are desirable or not depends upon their compatibility with resource management objectives for the area. Many of these changes are, in reality, vital to a healthy ecosystem. The following list of fire related ecosystem functions was originally set forth by Wright and Heinselman (1973) and modified for more southerly conditions by Wade and others (1980):

A. Fire influences the physical-chemical environment by:

1. Directly releasing mineral elements as ash
2. Indirectly releasing elements by increasing decomposition rates
3. Volatilizing some nutrients
4. Reducing plant cover and thereby increasing insolation reaching the forest floor
5. Changing soil temperatures because of increased insolation

B. Fire regulates dry-matter production and accumulation by:

1. Consuming the stems, foliage, and bark of plants
2. Consuming litter, humus layers, and occasionally increments of organic soil
3. Creating a reservoir of dead organic matter by killing, but not consuming, vegetation
4. Usually stimulating increased net primary production

C. Fire controls plant species and communities by:

1. Triggering the release of seeds
2. Altering seedbeds
3. Temporarily eliminating or reducing competition for moisture, nutrients, heat and light

4. Stimulating vegetative reporduction of top-killed plants
5. Stimulating the flowering and fruiting of many shrubs and herbs
6. Selectively eliminating components of a plant community
7. Influencing community composition and successional stage through its frequency and/or intensity

D. Fire determines wildlife habitat patterns and populations by:

1. Usually increasing the amount, availability, and palatability of foods for herbivores
2. Regulating yields of nut- and berry-producing plants, such as runner oak
3. Regulating insect populations which are important food sources for many birds
4. Controlling the scale of the total vegetative mosaic through fire size, intensity, and frequency
5. Regulating macrovertebrate and small-fish populations

E. Fire influences insects, parasites, fungi, etc., by:

1. Regulating the total vegetative mosaic and the age structure of individual stands within it
2. Sanitizing plants against pathogens, such as brownspot on longleaf pine
3. Regulating the numbers and kinds of soil organisms
4. Creating microsite conditions that favor one fungus over another, such as _Trichoderma_ spp. at the expense of _Heterobasidion annosus_.

Fire also affects evapotranspiration patterns and surface waterflow, changes accessibility through, and aesthetic appeal of, an area, releases combustion products into the atmosphere, and produces charcoal which can stimulate ectomycorrhizae as well as affect the global carbon budget and quantity of CO_2 in the atmosphere.

Many of these processes and functions can be influenced by regulating the intensity and timing of a fire. Fires can be set at specified intervals during particular physiological stages of plant growth under selected fuel and weather conditions.

History of Prescribed Fire

On the Coastal Plain of the Southeastern United States, the Indians long ago recongnized certain fire effects were very desirable and, thus, began using fire as a management tool. The extent to which the American Indian used fire so surprised the early European visitors to the South that they often commented in their journals. For example, Bartram traversed the longleaf pine (_Pinus palustris_) belt in 1773 and reported that not only were lightning fires common, but that the Indians used fire almost daily throughout the year to "raise" game (Bartram 1791).

According to the accounts of early settlers and travelers to the Southeast, the Indians also used fire to stimulate early grass growth to attract game, to keep the woods open for better accessibility and hunting by controlling the underbrush, and, perhaps, in warfare (Demmon 1935; Harper 1962).

The original white settlers in this region were primarily interested in agriculture and cattle--not trees. Fire was their primary range management tool and they used it extensively; they were not particularly concerned with the silvicultural aspects of fire although these were mentioned in the literature as early as the 1840's (Harper 1962).

Centuries of annual burning, first by the Indians and then by the European settlers, in conjunction with lightning fires, resulted in a lush grass understory and open parklike overstory of longleaf pine--the "only" species whose seedlings can survive low intensity annual winter fires (Garren 1943). However, Little and Dorman (1954) infer (and I concur) that south Florida slash pine (Pinus elliottii var. densa) seedlings are also capable of withstanding annual winter fires although not to the extent of longleaf pine. Typical slash pine (Pinus elliottii var. elliottii) seedlings are not fire resistant. This species was originally more common on wetter areas such as pond margins and wet "savannas" that occasionally experienced a fire-free interval of 5 or 6 years--enough time to allow the slash pine saplings to develop some resistance to fire.

As the South was logged over around the turn of the century, the "cut-out and get-out" attitude fostered carelessness with fire while the logging debris resulted in intense fires that killed any remaining pine regeneration or cull trees, thereby destroying the seed source over vast areas.

Little differentiation was made between these fires and those used during the previous hundreds of years. All fires were considered destructive and complete fire exclusion was attempted on many large southern landholdings during the next several decades. This experiment was a failure. Prohibiting the cattleman from legally using fire simply resulted in a dramatic increase in incendiary fires. With several years of fire exclusion, fuel would build up, needle drape would become a factor, and the inevitable fires would tend to be intense, killing pine as well as hardwood. On those areas that escaped wildfire, climax hardwoods such as sweetgum (Liquidambar styraciflua), southern magnolia (Magnolia grandiflora), and oaks (Quercus spp. would either immediately overtop the more commercially desirable pine or form a dense midstory that would preclude pine germination and seedling survival when the mature pine eventually died or was cut.

In spite of the pressures applied by state and federal agencies, some private landowners continued to use fire; it was on these holdings and on USDA research plots that the principles of southern pine management emerged. Control of hardwood competition, exposure of a mineral soil seedbed and, perhaps most importantly, periodic reduction of the fuel buildup were all management needs. Well-planned, low-intensity prescribed fires could accomplish these essential tasks as well as produce range and wildlife benefits.

Several very bad fire seasons of the 1930's were harbingers of an increase in the number of managers who began using prescribed fire to reduce hazardous fuel accumulations. U.S. Forest Service policy was changed to allow prescription burning on national forests after the disastrous 1943 wildfire losses, which were magnified by the wartime lack of available men and equipment. Guidelines for using prescribed fire in the management of slash pine appeared that same year (Bickford and Curry 1943). Since then, numerous manuals have appeared that explain how to use prescribed fire to accomplish a variety of resource management objectives on several million acres prescribed burned annually within the slash pine range. One of the best is "A Guide to Fire by Prescription" by M. Dixon which has been updated several times since publication in 1965.*

PRESCRIBED FIRE USES

The range of slash pine has been extended westward to the Coastal Plain of East Texas and eastward to the sandhills of the Carolinas. This area encomapsses two general fuel types, the pine-bluestem type in the west and the pine-wiregrass type in the east, as well as many ancillary plant associations. Descriptions of the flora are summarized by Komarek (1974b). Although the details of applying prescribed fire vary across the slash pine region, the underlying principles remain the same.

Hazard Reduction

The most common use of prescribed fire in both plantations and natural slash pine stands is for hazard reduction. For example, over 70 percent of the forest acreage prescribed burned in Georgia during 1972 was for this purpose (Figure 1). Herbaceous fuels often create a dangerous fire hazard in the first few years after planting. After about age 4 or 5, slash pine becomes somewhat fire tolerant; its bark begins to thicken; and its rapid juvenile growth puts the crown above these flashy grass fuels. If prescribed fire is not used, however, fire hazard will become progressively worse over the next several decades as litter fuels accumulate, flammable understory shrubs increase in size, and needle drape develops (Johansen 1968) (Figure 2, A and B). Understory fuels provide a pathway into the pine crowns where the uniformness of the canopy encourages crown fires. Furthermore, in both close-spaced plantations and dense natural stands it becomes difficult or impossible to move firefighting equipment through the area, once the trees reach about 6 inches d.b.h.

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*Available from the Southern Forest Fire Laboratory, P.O. Box 5106, Macon, GA 31208, as "A Guide for Prescribed Fire in Southern Forests" by Mobley and others 1978.

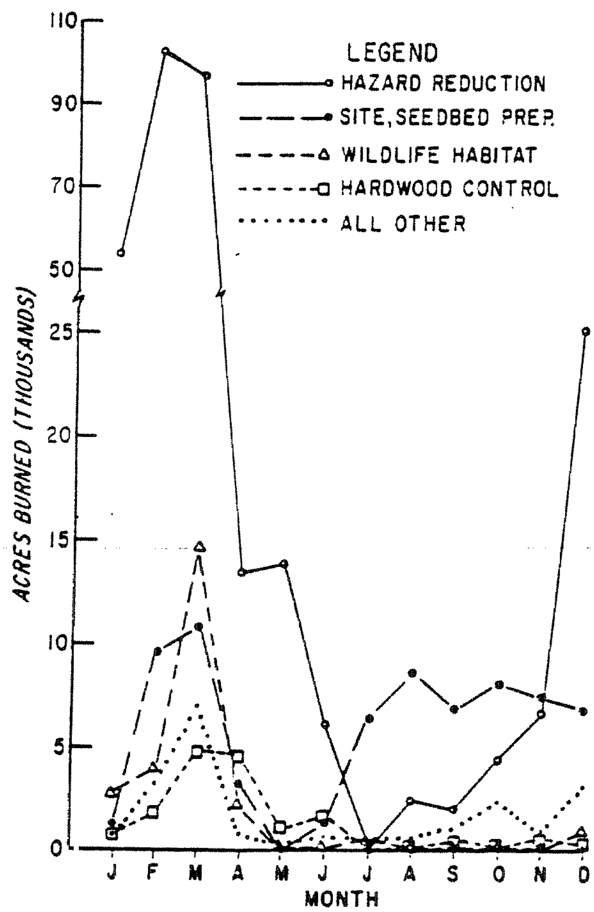

Figure 1.--Monthly variation in acreage prescribed burned for selected objectives in Georgia, 1972 (Hough and Turner 1974).

Weddell and Ware (1935) burned planted slash pine plots to determine seedling mortality. Three percent were alive after three annual fires, the first at age 1, and 32 percent survived a single burn at age two. In south Florida, Ketcham and Bethune (1963) reported that less than 0.1 percent of the typical slash pine survived a wildfire 2 years after planting. In contrast 23 percent of south Florida slash pine burned by head fires survived, and 56 percent of the seedlings burned by a backing fire survived. Chapman (1944) stated that a "really hot fire" is required to kill 100 percent of 3- to 4-year old slash pine.

Figure 2.-- (Next page) Effect of two fire management regimes in a mature slash pine stand, north Florida. A (above) after 20 annual winter fires; understory fuels averaged 1500 lbs/a and litter fuels 4000 lbs/a. B (below) with fire exclusion the estimated understory and litter fuel weights were 4000 lbs/a and 25,200 lbs/a, respectively.

How soon a stand of slash pine can withstand its first fire is more dependent upon associated fuel conditions and site index than upon age. Mann and Whitaker (1955) successfully prescribed burned 4-year old slash pine averaging 6 feet tall that had been grazed. Bickford and Newcomb (1947) stated slash pine 6 feet tall can survive a slow-moving winter prescribed fire. Slash pine less than 5 feet tall is easily killed by even a light fire according to Cooper (1965). He states that fire should be excluded from slash pine plantations until the trees are at least 10 feet tall. Even with intensive site preparation that eliminates most of the hazardous fuels prior to planting, relatively safe burns cannot be scheduled until the trees are 15 feet tall. Gruschow (1952) and McCulley (1950) also recommended a minimum height of 12 to 15 feet.

The first prescribed fire in a stand is usually the most difficult to administer. Waiting for the trees to get larger doesn't necessarily make the task any easier, however, and exposes the stand to that many more years of risk. The individual resource manager has to decide when his prescribed fire program can be implemented in a given stand. Factors such as proximity to public roads, incendiary activity, and the fuel hazard on adjacent areas must all be evaluated. After the inital fire, the stand can be reburned whenever the resource manger decides fuel accumulation is becomming excessive. Twenty years of burning on our north Florida study plots in the gallberry-sawpalmetto fuel type has demonstrated that head fires in roughs older than 3 years can scorch even mature slash pine (Sackett 1975). A comparison of wildfire size with age of rough, in this same area, showed a marked increase in acreage burned on roughs over 5 years old (Davis and Cooper 1963). The ameliorating effects of recent prescribed burned areas upon wildfire intensity, damage, and control have also been documented (Helms 1979; Mann 1947). As mentioned by Cooper (1965), plantations are much easier to prescribe burn than natural stands because of more uniform conditions.

Fuel accumulation seems to be a function of latitude. In south Flroida it appears as though fuel accumulation and decomposition reach equilibrium within 10 years, in north Florida about 20 years, and in middle Georgia and South Carolina over 25 years (Unpubl. data, Southern Forest Fire Laboratory, Macon, GA). Results from a natural slash-longleaf stand in north Florida showed both litter and understory fuels continued to increase through 21 years of fire exclusion, but the rate of increase has slowed appreciably since Sackett (1975) reported the 12-year results. Average weight of the forest floor after 21 years was 12.6 tons/acre.

The cost of hazard reduction burning in the slash pine belt is cheap insurance. Vasievich (1980) found that the cost varied with the size of the burn and age of rough on southern Coastal Plain national forests, ranging from $0.35 to $4.82 per acre. The cost of burning high-fuel hazard areas in southwest Florida by the Florida Division of Forestry during the 1977-1978 season averaged $0.27 per acre (Wade and Long 1979), which is lower than can generally be anticipated. Mook and others (1977) reported costs from $1.22 per acre for less difficult areas to $2.57 for more difficult southern Coastal Plain areas. Alig and others (1981) compared alternative management strategies in 9- to 15-year old slash and loblolly pine plantations in Mississippi. They found all three management schemes tested, including those involving the use of prescribed fire, produced rates of return better than 6 percent above the general inflation level.

Naval Stores

Slash pine has been the preferred naval stores species for over three centuries, as described by McReynolds (This Volume). Historically, each worked tree was raked around every winter and the orchard burned with a low-intensity fire. The objectives of this "light burning" were to reduce the wildfire hazard, improve accessibility, and increase gum yield. If the burn was conducted without scorching the worked trees, yields increased about 4 percent the following year (Harper 1944). On the other hand, yields decreased with increasing crown scorch. Continued turpentining of severely scorched and defoliated trees is likely to kill them. As would be expected, the exposed faces are very susceptible to fire injury, burning intensely once ignited and often resulting in a "dry face", necessitating abandonment of the tree.

Even though the labor-intensive practice of raking around each worked tree is not economically feasible under present conditions, annual winter backfires under marginally damp conditions can be safely used. If the fire will carry, it will do its job in a 1-year rough.

Pruning and Thinning

Since prescribed fires in young slash pine stands often scorch the lower branches, the possibility of using fire as a pruning tool has often been suggested (Albert 1957). Fire pruning might prove feasible in dense, even-aged stands if we learn to regulate fire intensity better than we presently can. In the only study I am aware of, Bruce (1952) found that head fires in a poorly-stocked 9-year old plantation did prune some lower limbs, but any benefits were overshadowed by a resultant loss of growth from the fire damage.

Albert (1957) also suggested the possible use of fire as a thinning tool. An unwanted understory of pine established beneath an immature pine stand could be eliminated with a well-planned prescribed fire (Balmer and Williston 1973). Perhaps the biggest drawback to using fire as a thinning agent is that the burner can exercise virtually no control over the spacings of survivors. Nonetheless, the use of fire in overcrowded young stands of other southern pine species has proved successful (McNab 1977; Maple 1970; Nickles and others 1981). Crow and Shilling (1980) conclude that the use of fire to thin dense, young pine stands has obvious risks and research results are scanty; but the potential payoff is precommercial thinning accomplished at a fraction of the cost of any other method.

Range Management

One method of reducing the fire hazard in young slash pine plantations is to graze them (Wilson and Collins 1979). Trees and cattle have coexisted on the southern Coastal Plain for several centuries and methods for their integrated management are described by Lewis (This Volume).

Cattle tend to concentrate on fresh burns and, if not kept off until there is enough to eat, can do considerable damage (Halls and other 1964; Hughes 1975). Herbage utilization is greatest the year following burning and decreases rapidly to only about 18 percent after 3 years on longleaf pine-bluestem ranges (Duvall and Whitaker 1964). A 3-year burning rotation has been advocated on both pine-bluestem and pine-wiregrass ranges (Duvall and Whitaker 1964; Pearson and Whitaker 1973; White and Terry 1979).

Wildlife Habitat Improvement

Periodic fires to provide range management benefits can be timed to also benefit wildlife (Hughes 1975). The effects of fire on wildlife are primarily indirect through habitat manipulation (See Buckner, This Volume). Even wildfires rarely result in wildlife mortality except during the nesting season. A good summary of the direct effects of fire on fauna appears in Lyon and others (1978). Any animal losses are generally made up for by the increased carrying capacity of the newly-burned area.

Since different species require different habitats, a prescribed burning program for wildlife will depend upon the species targeted for management. Those requiring a dense undergrowth will not be abundant on a fresh burn and, conversely, species desiring an open habitat will decline as succession progresses. A well-planned wildlife burning program will produce a mosaic of burned and unburned areas, thereby meeting the needs of many species.

In upland pine stands legumes may be a major source of seed for several species including the bobwhite quail. Burning generally favors these legumes (Campbell 1955; Cushwa and others 1966; Garren 1943; Landers and Johnson 1976). According to Moore (1972), quail production in south Florida is enchanced by burning one-third to one-half of a management block per year on a 2-year rotation, completing the burns before nesting begins in March. In north Florida and south Georgia, annual burning for quail management has been practiced for generations with excellent results (Komarek 1963). Harshbarger and Simpson (1970) reported that quail prefer fresh burns and 1-year roughs as late summer nesting sites. Buckner and Landers (1980) suggest a 2-year burning cycle is best where ground-level vegetation is not dense--as in many areas of the Georgia Piedmont.

Burning has been found to stimulate the fruit production of several desirable wildlife species such as dogwood (*Cornus florida*) (Lay 1956; Stransky and Halls 1979), huckleberries (*Gaylussacia* spp.) and blueberries (*Vaccinium* spp.) (Johnson and Landers 1978). Summer burns to stimulate mast production of runner oak have been tried with mixed results on the Florida National Forests. Johnson and Landers (1978) found runner oak acorns were most abundant 2 years after burning in mature slash pine plantations. Desirable deer-food plant species are increased by fire, often through sprouting, which also brings these plants back within reach of browsers such as deer (Lay 1956; Stransky and Halls 1979). Thus, a 3- to 5-year burning cycle is recommended for turkey and deer management (Byrd and Holbrook 1974; Johnson and Landers 1978: Stoddard 1963). April and May prescribed fires should be avoided when managing for turkey because this is their peak nesting season (Buckner and Landers 1980).

If wildlife is to be a consideration in slash pine management, target species should be selected and the prescribed fire program tailored to their needs.

Control of Understory Species

Periodic wildlife burns also keep understory hardwoods at a manageable level. Since slash pine is a seral species in the southern mixed hardwood climax forest, the understory hardwoods will take over if not kept in check (Figure 3). These successional trends are especially serious in the south Florida slash pine forests of southeast Florida where the process takes less that 25 years (Robertson 1953; Wade and others 1980) and in the upper Coastal Plain and Piedmont where the slash pine range has been extended by planting (Chaiken 1949; Heyward 1957). Where moisture availablility limits tree growth, eradication of the hardwoods may result in increased pine growth (Balmer and others 1978; Cain and Mann 1980; Clason 1978; Grano 1970b; Loyd and others 1978; Nelson and others 1981; Williston 1978). Understory control prior to harvest also reduces marking and logging costs (Klawitter 1959; Lawrence 1968).

Fire can be used as a hardwood control mechanism because southern hardwoods are less fire resistant than southern pines. The susceptibility of hardwoods to fire is largely size dependent. Once larger than 4 to 5 inches dbh, they become difficult to kill without also destroying the pine (Brender and Cooper 1968; Chen and others 1975; Ferguson 1961). Fire tolerance is also a function of species, with sweetgum being one of the easiest trees to topkill and oak being one of the more difficult (Brender and Cooper 1968; Chen and others 1975; Ferguson 1961).

Damage to plants increases with fire intensity. It is therefore desirable to use as intense a fire as possible without injuring the pine. Hodgkins (1958) stated that fires "....hottest near the groundline do the most damage to small hardwoods". Lindenmuth and Byram (1948) determined that backfires were significantly "hotter" than head fires near ground level in the longleaf pine-grass fuel type whereas Davis and Martin (1960) found the opposite to be true in palmetto-gallberry roughs.

The best season to burn for hardwood control has still not been precisely determined, but we do know it is not during the winter. Chaiken (1952) found that five annual winter fires did not decrease hardwood sprouting vigor, and Langdon (1982) presents data showing a four-fold increase in hardwood stems less than 4 inches dbh after 30 annual winter fires on the South Carolina Coastal Plain. In contrast, a series of close-interval summer fires will generally eradicate many rootstocks (Chaiken 1949; Chen and others 1975; Ferguson 1961; Grano 1970a; Lotti and others 1960), although Silker (1955) found no relation between topkill and season of the year. In east Texas, spring fires

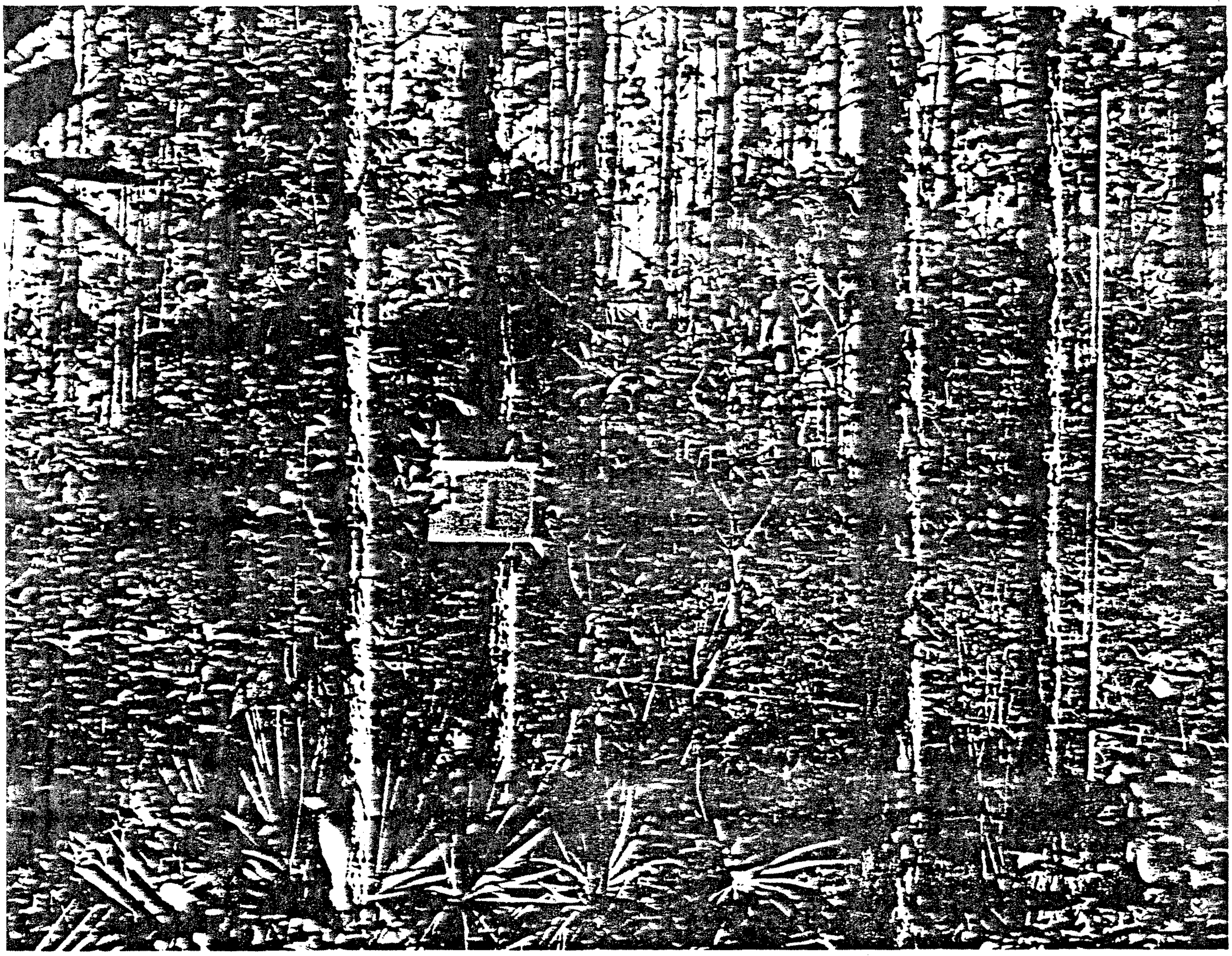

Figure 3.--Hardwoods have taken over this south Florida slash pine stand after 12 years of fire exclusion (photo by Dr. R. Hofstetter, University of Miami).

produced satisfactory results (Ferguson 1957, 1961; Harrington and Stephenson 1955), but summer fires were slightly better (Ferguson 1957, 1961). In the lower Piedmont of Georgia, Brender and Cooper (1968) found that fuels did not accumulate fast enough to allow intense biennial summer fires; thus, their low-intensity repeat burns did not result in much additional rootstock kill. Whether differences exist between early and late summer fires is not known. Hodgkins (1958) believed the increased hardwood kill from summer fires was associated with carbohydrate reserves which are at their low point in early summer. Wenger (1953), however, presented evidence that both the number and size of sprouts, at least of sweetgum, are more likely regulated by a hormone system than by food reserves.

Because of benefits to wildlife, the resource manager may simply want to keep the hardwoods in check rather than eradicating them. Langdon (1971) reported hardwood vegetation will recover to its prefire state within 5 to 7 years. One compromise is to prescribe burn on a 3- to 5-year rotation (1- to 2-year rotation for quail) to keep the hardwoods small, providing food and cover for wildlife. Then, just prior to harvest, successive summer burns can be used to reduce the need for expensive site preparation treatments before reforestation.

Seedbed and Site Preparation

Prescribed fire is almost universally a part of reforestation preparation. The germination and survival of slash pine, like other southern pines, is best on mineral soil (Cooper 1957; Osborne and Harper 1937), although it can become established without mineral soil exposure, provided seed source is adequate (Cooper 1957; Langdon and Bennett 1976). Stands regenerated without any seedbed or site preparation treatment generally must compete with an established understory for nutrients, water and sunlight--a situation that overwhelms most slash pine germinants. Because this understory is usually comprised of such species as waxmyrtle, palmetto and gallberry that release more heat energy when burned than do the pioneer herbaceous fuels that predominate after site preparation, prescribed burning must be postponed until the stand is much older, thereby subjecting it to potential wildfire loss for a longer period (Langdon and Bennett 1976). Furthermore, logging debris from the previous stand presents a serious fire hazard for the first 2 to 3 years. Other advantages of site preparation are summarized by Balmer and others (1976), and Lohrey and Jones (This Volume).

The amount of necessary site preparation is dependent upon such things as the amount and size of both dead and live fuels on the site, expected seed crop, season of harvest, weather conditions, and management objectives. Prescribed fire may be the only preparation necessary if logging debris is mostly less than 2 inches in diameter, or if only a litter bed is present, or if little brush or few hardwoods are present. But single fires cannot be expected to consume logging debris much over 2 inches in diameter or kill residual brush and hardwoods.

In the last several years, most sites have been routinely prepared using a combination of fire and machines (Fox 1970). Here, fire is used to enable equipment operators to more easily see the stumps, to dispose of piled debris, or to ensure more tightly-packed beds. In fact, mechanical operations are often delayed until the site has been burned. Wade and Wilhite (1981) reported that, on the Coastal Plain of Georgia, delaying planting so an area could first be prescribed burned would not be economically justifiable if the resulting fire were of low intensity.

As replacement costs and fuel costs for mechanical equipment continue to escalate, such routine operations as chopping, shearing, bedding, furrowing, or harrowing will have to be critically appraised (See also Broerman and others, This Volume). Fire and natural regeneration techniques could be substituted for current planting practices (Wade and Ward 1976).

On rough terrain and on very wet sites, chemicals may take the place of mechanical equipment (Fox 1970). On such sites, fire can be used in conjunction with herbicides to achieve a higher vegetation kill and to clear the surface for easier and safer movement during planting. In the last 10 years, however, government regulations pertaining to the use of chemicals have curtailed this option.

Slash pine seedbed and site considerations are treated in more detail elsewhere in this volume. Good summary articles include Balmer and others (1976), Derr and Mann (1971), and Williston (1980).

Disease and Insect Management

Belanger and others (This Volume) treat the general topic; the paragraphs below refer only to reported use of prescribed fire. A large-scale study in industrial slash pine plantations throughout the southern Coastal Plain has demonstrated that fire can help control the severity of annosus root rot (Froelich and others 1978).

Lotan and others (1981) discuss the potential use of prescribed fired to help control fusiform rust. Small decreases in the number of cankers on young slash pine on areas prescribed burned during site preparation have been documented (Wade and Wilhite 1981).

Although no relation has been found between prescribed burning and southern pine beetle attack, Belanger (n.d.) believes the association between this pest and fire deserves additional study. Hedden (1978) states the only available method to reduce the risk of southern pine beetle attack is to practice intensive forest management including the use of prescribed fire.

Fox and Hill (1973) showed that burning after clearcutting was a deterrent to the pales weevil, but had no effect on the attractiveness of a site to the pitcheating weevil. However, Speers and Ebel (1971) found that fall disking and burning 1-year old logging debris in north Florida resulted in an immediate renewal of weevil attraction on the area. Additional investigation will be necessary to resolve these appraently contradictory research results.

Parmeter's (1977) summary of the beneficial and harmful effects of fire on forest diseases has also been reproduced in Lotan and others (1981).

Fitzgerald and others (1977) reported Seymeria cassioides, a root parasite of slash pine, is a fire follower; whereas Grelen and Mann (1973) suggest spring prescribed fires can be used to control this annual. Although there is still much to be learned it will behoove the manager to write his prescription to minimize mineral soil exposure whenever it is anticipated that seymeria may come in after a burn.

Aesthetic and Recreational Opportunities

Fire has a place in the aesthetic management of the slash pine ecosystem. It can be used to open up vistas as in Everglades National Park (Klukas 1973) or to enhance the general scenic quality of forest landscapes (Komarek 1974b; Meskimen 1971). It increases diversity and eliminates the solid wall of vegetation on either side of a roadway, allowing one to see into the stand. Prescribed fire can enhance blueberry (Coggin and Engle 1971) and blackberry production, and increase the numbers and visibility of wildflowers as well as wildlife. Perkins (1971) mentions that opportunities for outdoor photography and bird watching are improved. He sums up the outdoor recreational values of prescribed burning by stating it benefits campers, picnickers and hikers, as well as motorists enjoying the scenery.

The resource manager must remember that the use of fire in high-exposure areas can also have the opposite effect on the public, particularly when the results of a poorly conducted or ill-timed prescribed fire are in evidence.

OTHER ENVIRONMENTAL EFFECTS

All fires produce change but this fact is sometimes mis-translated to "all fires produce damage". A more rational approach is to regard fire like any other natural force--under harness it can be used to man's advantage; out of control it can have disastrous results. If the Southeast is truly a fire environment, however, fires will continue to occur as they have in the past in spite of any effort to exclude them. Thus well-planned prescribed fire will do much less damage than wildfire. This broader perspective and the role of fire in southern ecosystems are well discussed by Christensen (1977).

Whether or not damage actually occurs, the potential for it is associated with every fire. Thus, in considering prescribed fire as one of the alternative solutions to a forest problem, tradeoffs between anticipated benefits and possible damages should be evaluated.

Soil Effects

According to Wells and others (1979), the key to soil response is the intensity of the fire and its resultant exposure of mineral soil. Most prescribed fires in the slash pine ecosystem are of low intensity and short duration, minimizing adverse effects. Piling and burning logging debris subjects the soil beneath to more prolonged heating, but adverse effects seem absent under southern conditions as indicated by the rapid regrowth of vegetation on such microsites.

Continued exposure of mineral soil to the force of rain can result in some soil pores becoming clogged with ash and carbon particles (Pritchett 1977). This may lead to reduced infiltration and aeration.

Most studies in the southeastern Coastal Plain have concluded that neither prescribed nor wildfires have much impact on the soil physical properties governing infiltration or erosion (Metz and others 1961; Moehring and others 1966; Pritchett 1977; Ralston and Hatchell 1971; Stone 1971; Suman and Halls 1955). I have observed decreased infiltration rates during extended wet periods on Leon sands in north Florida after a decade of annual winter head fires, but erosional consequences were negligible.

In the hilly country of northern Mississippi, Ursic (1969, 1970) documented increased overland flow on steep slopes after prescribed burning on soils with a fragipan. In the Georgia Piedmont, however, even intense summer storms failed to initiate erosion after prescribed burning (Brender and Cooper 1968). Likewise, Cushwa and others (1971) in the south Carolina Piedmont failed to detect soil movement, even in established gullies, after prescribed burning.

A fire consuming the organic mantle covering the soil would seem to have pronounced effects on the nutrients stored there. Wells and others (1979) summarized many of these changes. Repeated burns, 4 years apart, have little longterm effect on the forest floor or underlying soil, whereas the result of continued annual burning is to incorporate organic matter and the nutrient pool orginally in the forest floor into the upper A horizon. Although some nitrogen is lost during burning though volatilization, it is apparently replaced, perhaps by the influx of nitrogen-fixing plants. Viro (1974) has held that this volatilized N is unimportant because before burning it is in a form unavailable for use by plants.

McKee (1979) recently reported on the soil chemical properties of a Leon sand in north Florida after almost two decades of annual winter prescribed burning. He found that prescribed burning increased soil pH, nitrogen, water soluble and available phosphorus, exchangeable bases, and organic matter content in the surface 0- to 3-inch soil layer. He concluded that on the Coastal Plain prescribed burning under a pine overstory may, in fact, be beneficial to nutrient cycling.

Fire has a direct, obvious effect on soil and litter-layer micorbial populations. As summarized by Wells and others (1979), 20 annual winter burns did not inpair soil metabolic processes, although microorganism populations were altered.

Effects on Water Resources

Tiedmann and others (1979) recently summarized the effect of fire on water resources. The major concerns involve the potential for increased runoff. With increased runoff, less water is stored in the soil, erosion and resulting sedimentation can increase, and fire-mineralized nutrients can be washed off the site. In the Southeast none of these appear to be a problem with well-conducted prescribed burns.

Care should always be taken to preserve stream-side vegetation, but this is generally not a problem when burning under an overstory. In fact, these damper microsites are often utilized as block boundaries eliminating the need for plowed lines. As a rule, it is not necessary to plow out any interspersed ponds or bays either, when burning under recommended weather conditions.

Effects on Air Quality

Combustion products produced in a fire have an obvious effect on the atmosphere. Although carbon dioxide and water are the major products, particulates are responsible for the decrease in visibility caused by smoke. Reduced downwind visibility is the most common complaint associated with prescribed burning in the slash pine ecosystem, but smoke contains other chemical compounds, some of which can have detrimental health effects.

The best way to minimize smoke-related problems is to plan ahead and manage the smoke as well as the fire itself. The major consideration should be to keep the smoke from sensitive downwind areas such as highways, airports, and populated zones. Excellent prescribed burning results can be achieved with nighttime burning (Sackett and Wade 1970), but it must be well planned. Nighttime inversions, common during the burning season, concentrate the smoke in low areas and can cause significant visibility problems along highways, especially where they cross swamps or streams.

The most comprehensive written aid is "Southern Forestry Smoke Management Guidebook" (USDA Forest Service 1976), but other brief guidelines exist (Tangren 1976; Ward and Dieterich 1970). Lamb (1969) discussed some conditions favorable for nighttime burning in the lower Georgia Piedmont and the number of nights such conditions can be expected.

PRESCRIBED BURNING CONSIDERATIONS

The following discussion may prove helpful in interpreting material presented in the various prescribed fire guides (e.g., Mobley and others 1978), but it is no substitute for that information.

Desirable prerequisites to the use of fire for any purpose include: (1) A definable management problem(s) on a specific area that fire will prevent, correct, or alleviate; (2) determination of acceptable fire damage limits; (3) determination of the phenological stage of vegetation, season to burn, and fire behavior that will produce the desired effects while minimizing costs, deleterious side effects, and damage potential; and (4) knowledge of the mix of fuel and weather conditions, type of fire, and firing technique that will produce the desired effects in the fuel type in question. An evaluation of the burn results is also necessary if the burner is to learn from his experience. Inability to quantify fire behavior-fire effects relationships is a major deterrent to the increased use of fire in the slash pine ecosystem.

Fire Behavior

The impact of fire upon an area depends upon fire behavior, site parameters such as soil type, and pre- and post-burn conditions such as soil moisture. The behavior of fire is generally qualitatively described, but descriptors such as "fast moving" or "cool" mean different things to different people. A method of quantifying fire is needed, but a simple, reproducible predictive method has yet to be devised. Byram's fireline intensity (the rate of heat energy released per unit length of fire front per unit of time) is often used to describe fire behavior (Brown and Davis 1973), but it is by no means an ideal solution. Functionally, it is:

$$I = Hwr$$

where

I = fire intensity in Btu's/ft/sec (kW/m)

H = heat yield in Btu's/lb of fuel (kJ/kg). The value of 6,000 (1400) can be used for all slash pine ecosystem fuels.

w = weight of available fuel (fuel that will be consumed in a given fire) in lb/ft^2 (kg/m^2).

r = rate of spread of the fire front in ft/sec (m/sec)

(metric equivalents in parentheses)

Table 1 helps put hypothetical fire intensity ranges in perspective. South Florida slash pine, being much more fire resistant, can withstand intensities greater than those listed in Table 1.

Fireline intensities above 200 Btu's/ft/sec are often utilized in broadcast burns following clearcutting to dispose of the larger sized materials present. If practical and safe, ignite the center of the area first and after the fire becomes well developed, light the perimeter. If correctly timed, the flames will draw toward the center fire leaving the control lines free of smoke and making fire control much easier. Strong surface windspeeds are ordinarily avoided when conducting this type of burn. Select an upper wind direction that will avoid smoke-sensitive areas (USDA Forest Service 1976).

Different combinations of rate of spread and fuel consumed can yield equivalent fireline intensities. For example, a head fire prgressing at 10.75 ch/hr (0.21 km/hr) through a 1-year rough consisting primarily of grass fuels and pine needles weighing approximately 1.5 tons/acre (3.71 t/ha.) will result in an intensity of 81 Btu's/ft/sec (280 kW/m), as would a backfire moving at 2 ch/hr (0.04 km/hr) through a 6-year old palmetto-gallberry rough with 8 tons/acre (19.77 t/ha.) available fuel. The effects, however, may not be the same because of the longer residence time of a backfire.

A headfire will yield a higher fireline intensity than a backfire under a given set of burning conditions, but the total heat energy produced at a given location in the burn may be about the same because the backfire will take longer to move across the point in question (residence time), thereby influencing it for a longer period of time. As a general rule, head fires should not be used in palmetto-gallberry roughs older than 2 to 3 years because damage to the overstory is likely to be unacceptable (Sackett 1975). Several rate-of-spread ranges have been reported for heading and backing fires in southern pine (Hough and Albini 1978; McArthur 1971; Van Loon and Love 1973). Rates of spread of prescribed head fire in slash pine are strongly influenced by wind and can exceed 25 ch/hr, although 10 ch/hr is closer to the norm. Backfire rates of spread, on the other hand, although also slightly increased by an increase in windspeed, are confined to a narrow range between about .075 and 3 ch/hr and average between 1 and 2 ch/hr.

Table 1.--Fireline intensity ranges and associated behavior of head fires.

Fireline Intensity			Flame Length[1]			Fire Behavior[1]
Btu's/ft/sec		kW/m	ft		m	
20	=	69	.5	=	.2	Intensity probably too low. Very patchy burn. Scorch not a problem.
21- 75	=	73-260	.5-2.5	=	.2- .8	Optimum range. No fire control difficulties. Scorch heights generally below 15 ft (4.6m).[3]
76-125	=	263-432	2.5-3.5	=	.8-1.1	Generally too hot for use in immature stands; use a backfire. Scorch heights 20 to 30 ft (6.0 to 9.1m).[3] If downwind plowline not backlined, head fire may cause some control difficulties.
126-200	=	463-692	3.5-5.0	=	1.1-1.6	Upper limits for burning under a stand. Scorch heights may be excessive even with persistent wind.[3] Always backfire downwind side of plot first. Think twice about using head fire. Have tractor-plow unit standing by.

1 Byram's relationship between flame length and intensity, ($h = 0.45I^{0.46}$), overestimates flame length (h) at low intensities and thus estimates based on the author's experience were used.

2 Van Wagner's (1973) scorch heights were slightly reduced to better represent observations in southern pine forests.

3 Moderate, persistent in-stand winds and low ambient temperatures will result in lower scorch heights.

Crown Scorch

Percent of crown scorched is probably the most important parameter in a prescribed burning plan for it determines the level of acceptable damage. Cooper and Altobellis (1969) stated that mortality in young loblolly pine was primarily caused by damage to the tree crowns rather than by damage to the stem cambium. Van Wagner (1973) found good correlation between crown scorch and Byram's fireline intensity and utilized this relationship to develop an equation for estimating lethal scorch height. It is:

$$h_s = \frac{3.94\ I^{7/6}}{(0.107\ I + u^3)^{\frac{1}{2}}\ (60-T)}$$

where

h_s = lethal scorch height in meters

I = Byram's fireline intensity in kcal/m/sec

u = surface windspeed in m/sec

T = ambient temperature in °C

This relationship has not yet been validated for southern pines. Although the form of the equation seems reasonable, I believe the constants need modification since they appear to overpredict scorch heights in slash pine.

Slash pine is tolerant of crown scorch, as described by Balmer and Mobley (This Volume).

FACTORS AFFECTING FIRE BEHAVIOR

Fuels

Fuel, topography, and weather are major determinants of fire behavior. Even in the most severe fires, larger diameter live fuels are not all consumed. That fuel which is consumed in a given fire is defined as available fuel. A general rule of thumb to follow is that most dead fuels under 1/2 inch diameter, and live fuels less than 1/4 inch diameter will be consumed in prescribed fires. These amounts are estimated before burning to get an idea of the available fuel and, thus, fireline intensity. More exact consumption values can be determined by measuring fuels before and after burning, but this is rarely done on operational burns. Instead, various predictive guides based on parameters such as the understory species involved, age of rough, coverage and height of understory, and overstory density are used (Bruce 1951; Hough 1978; Hough and Albini 1978; McNab and others 1978; Sackett 1975).

Weather

Moisture has to be driven from a fuel before it will burn. In this way moisture content regulates fire behavior. With low humidities, persistent winds above 5 mph, and good fuel distribution, fire can move through live herbaceous fuels such a wiregrass (*Aristada stricta*) and bluestems (*Andropogon* spp.) when moisture contents are above 50 percent, but ordinarily dead fuels, either intermixed or beneath, are required. Dead fine-fuel moisture contents should lie between roughly 10 and 25 percent. Fire behavior rapidly gets out of hand when moisture contents fall below 10 percent, whereas above 25 percent the fire tends to go out, resulting in a patchy burn. On the southern Coastal Plain, fine fuels respond rapidly to changes in atmospheric moisture. Nelson (Unpubl. data at Southern Forest Fire Laboratory) determined that a 5/8 inch pine litter layer has a timelag of less than 30 minutes at 20 percent relative humidity and temperature of 82°F (28°C). If fine-fuel moisture contents are below 30 percent, they will follow the diurnal relative humidity cycle, falling during the day and recovering at night. The prescribed burner can capitalize on these daily fluctuations by timing his burn accordingly. To raise fuel moisture above 35 percent, either dew or precipitation is necessary. Dew is important only in that it regulates how early in the day one can get started; burning results will generally not be satisfactory until this moisture is "burned off" by the sun.

Regardless of fine-fuel moisture content, good burning results are seldom achieved when the relative humidity is above 60 percent. Conversely, below 30 percent relative humidity, fuels are easily ignited by small firebrands. Although excellent burns generally result when relative humidities are betwen 20 and 30 percent, only experienced burners should operate in this range because of the probable control problems from spotting unless specific firing procedures minimize this potential.

Most prescribed burning under a slash pine overstory is done in connection with winter frontal passages. If the site receives too much rain, it will not dry sufficiently to produce a good burn before the next system moves in. How much is too much depends upon how wet the fuels are prior to the rain, and how quickly they dry once the rain stops. This, in turn, depends upon the wind, relative humidity, amount of sunshine, and amount of canopy shade. Hough (1968) presents tables to help make this determination. If fuels are sparse or damp, head fires are usually needed because the flames will bend over the unburned fuels, drying and pre-heating them.

A successful burn should leave at least a thin, protective layer of charred material on the soil surface, but if the site is too dry, the litter layer will be completely consumed. If the soil itself is thoroughly dry, which is commonplace during the dry season in central and south Florida and can occur throughout the Coastal Plain during extended rainless periods, root damage to trees becomes more likely. Therefore, prescribed burning is not recommended when the pines are under stress because of depleted soil moisture.

Ambient temperature determines the amount of heating necessary to reach the lethal temperature for plant tissue, 140°F (60°C), and so affects the success of a prescribed fire. Excessive crown scorch is the usual result of burning in immature slash pine stands when the air temperature is above about 60°F (16°C). In south Florida, daytime temperatures rarely stay below 60°F for long, so most prescribed burns in the more fire-resistant south Florida slash pine have to be conducted at higher temperatures. Fortunately, in this section of Florida, surface wind speeds above 5 mph, which dissipate the heat from a fire and help keep it from the crowns, are common. For the same reason, good, persistent winds are desirable when burning beneath a tree canopy throughout the slash pine region. Thus, although in-stand windspeeds of 1 to 2 mph are enough to carry a fire, higher windspeeds will generally result in less crown scorch. If winds are much over 8 to 10 mph, however, head fire rates of spread and flame lengths may become excessive, increasing likelihood of damage and making control more difficult.

When using a backfire, high windspeeds are generally not a problem as long as they remain steady. Fluctuations of more than 90 degrees (± 45°) are a signal to the prudent burner to cease activities for the day because the fire front will quickly respond by changing to a flank or head fire, with an attendant increase in damage potential and control difficulties.

Topography

In the lower Piedmont, topography can partially compensate for a lack of wind. In laboratory burns, rates of spread doubled for approximately every 10-degree increase in slope above 20 degrees (Byram and others 1966). In the field, however, this doubling effect certainly seems to begin closer to a 10-degree slope than to a 20-degree slope.

PRESCRIBED FIRE TIMING

Once the decision has been reached that prescribed fire is the appropriate means to meet a resource management objective, the most crucial question is determining when to burn. This involves selection of the year, season, and time of day to burn.

The number of acceptable burning days during a given year is unpredictable, but almost always less than needed. Hence, resource managers should prioritize their burning schedules. A manager operating on a burning cycle for hazard reduction would give a recently burned stand a low priority. If enough good burning days did not materialize to get that stand burned, he would simply give it a higher priority the following year. The alternative is to be faced with areas in urgent need of burning as the end of the burning season approaches, tempting the manager to take a chance in burning on a marginal day. An illustration of a high-priority burn would be a 4- to 5-year old plantation in an area of high incendiary activity. Such an area might well be the top-priority burn on the first cold, windy day of the season--the philosophy being that any damage incurred would be far less than that from a springtime incendiary fire.

Season of the Year

It is not always easy to determine the best season to burn because each of the multiple benefits desired from a single fire has its own optimum time (Figure 2). For example, control of understory hardwoods is most effective during the summer when ambient temperatures are high, whereas hazard reduction burns are best carried out in the winter when the litter layer is drier. With some exceptions, however, most prescribed burning in slash pine ecosystem is done after the hard frosts in the fall have killed green grass but before the pines candle in the spring. Range management burns are often conducted in the spring; otherwise, this period is usually avoided because of wildlife nesting (although most game birds will re-nest), and because the pines are very susceptible to damage when new shoots are expanding. According to Martin and Dell (1978), dormant tissue can withstand longer exposure to high temperatures than active tissue. Objectives calling for summer burning are site preparation, control of understory hardwoods, and stimulating acorn production by runner oak (*Quercus pumila*).

If natural regeneration is the chosen method of reforestation after clear-cutting, fall burns prior to seed fall are recommended. Summer burns would allow competing vegetation to capture the site before the pine seed germinated, and winter burns would destroy seed already on the ground.

Another factor to consider when determining the season to burn is that damaged trees are more susceptible to insect attack. Pines damaged during a fall or winter burn have much more time to recover before the summer peak in insect activity.

Time of Day

Most prescribed burning takes place during the day because of safety considerations, and administrative and economic reasons. Moreover, burning conditions and smoke dispersion are generally best in the early afternoon. Some objectives, however, require a set of weather conditions that are best met at night. Two examples are the first hazard reduction burn in a young plantation, and the disposal of thinning slash in an immature plantation. If nighttime conditions can be utilized, the time available for prescribed burning can be significantly increased (Sackett and Wade 1970).

Firing techniques can be modified throughout the day as burning conditions increase toward afternoon, and then decrease toward evening as relative humidity rises and amibent temperatures and windspeeds decrease. Late in the day, dead branches and limbs that have been subjected to drying throughout the day will be more flammable than would otherwise be expected.

SUMMARY

Historically, fire was perhaps the most important ecological force determining what sites slash pine would occupy within its natural range and for how long. The early settlers observed that many fires produced desirable results and thus began using fire. As the management of forest lands intensified, values at risk showed a corresponding increase, which, coupled with the increase in man-caused fires, was reflected in higher wildfire losses. The primary use of prescribed fires thus shifted from range management to hazard reduction in the 1940's. Several million acres are currently prescribed burned each year in the slash pine belt to fulfill numerous resource management objectives. As costs of alternative treatments continue to escalate, I expect the returns from an active prescribed fire program will become even more attractive.

Besides the expected benefits from prescribed fire, there are both actual dollar costs and potential ecological and environmental costs associated with every fire. The objective comparison of these trade offs should be prerequisite to every prescribed burn. Desire, as well as undesired, fire effects vary with the burn objective and are dependent upon fire behavior which, in turn, is controlled by ignition pattern, fuel, weather and topographic conditions. These governing variables, including the role of moisture, are briefly described as they relate to changes in fire behavior. Fire behavior and its measurement are discussed as they impact upon slash pine survival and recovery after fire. The relationship between fire behavior and crown scorch is stressed.

Much of the fire effects literature is qualitative, fragmented and site specific, sometimes causing results to appear contradictory. For this reason a comprehensive literature treatment has been included to assist the reader in finding information pertinent to his particular needs.

FIRE

Slash pine gained its ecological niche in part by an ability to recover from light to moderate fire damage. Damage from fire often appears more detrimental than proves to be the case. Studies and case histories in South Carolina (Wade and Ward 1975), Georgia (Miller and others 1961), and Florida (Storey and Merkel 1960; McCulley 1950) indicate needle browning alone is seldom serious. Burning that results in light or no crown scorch (0 to 15 percent) may even enhance growth (Johansen 1975). Healthy slash pine as young as 5 years old may recover even with 100 percent crown scorch and a dead or damaged leader (Wade and Ward 1975). Data useful in determining fire damage are percent crown scorch, percent crown consumption, percent (height) bark char, age (plantations), diameter distribution, and stocking levels.

Observations following the 110,000 acre Buckhead fire in March, 1956 indicate that mortality in older stands of longleaf and slash pine can be estimated by the amount of crown consumed. Percentage mortality in large and small trees with the same amount of crown damage was approximately equal. Height of bark char on the stem as a percent of tree height also related to mortality. Height of bark char offers some advantage over crown scorch since the height is readily discernible and is independent of tree size (Storey and Merkel 1960) (Figure 1, Table 2).

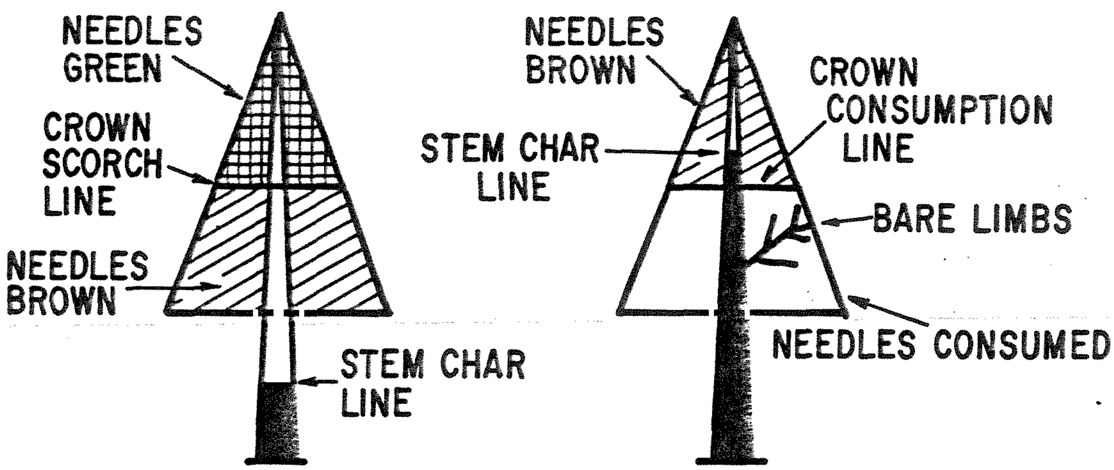

Figure 1.--Types of crown and stem damage. Stem char line is higher than crown consumption line in tree at right. Tree on left would live; trees on right probably would die (Storey and Merkel 1960).

In this instance all mortality took place within three months after the fire.

Miller and others (1961) observed recovery of slash and longleaf pine after the Muletail fire in December, 1954. The two growing seasons following the fire were droughty and not considered favorable for recovery of damaged tree. Slash pine survival after two years was as follows:

	Survival Percent
Cambium damaged	28
Healthy cambium	74
Dominant and codominants	79
Suppressed and intermediate	32
Dbh 6" and larger	80
Dbh less than 6"	26

Survival of both species combined, for dominants and codominants 6" dbh and larger, with healthy cambium was 82 percent. Ninety-two percent of the slash pine mortality had taken place by the end of the first growing season. Insects apparently played a minor role in mortality, but the investigators felt that an immediate light salvage would have risked build-up of bark beetle populations.

Table 2.--Mortality in slash pine stands three months after a March fire according to tree condition classes (From Storey and Merkel 1960).

Condition Class	Trees Sampled	Trees Dead After Three Months
	Number	Percent
Diameter, bh (inches)		
4- 6	80	31
7- 9	80	28
10-12	80	17
All	240	27
Crown Damage		
Heavy (50%) Consumption	48	90
Medium (1-50%) Consumption	48	44
Complete (100%) Browning	48	0
Heavy (91-99%) Browning	48	0
Medium (50-90%) Browning	48	0
All	240	27
Stem Damage (% height charred)		
Heavy (81-100)	64	88
Medium (61-80)	17	24
Moderate (41-60)	31	13
Light (21-40)	81	0
Very Light (0-20)	45	0
All	238	27

McCulley (1950) related crown damage to mortality in trees less than 6" dbh in natural slash pine stands on the Osceola National Forest, Florida (Figure 2). Slash pine over 5 feet tall seldom died if less than 70 percent of the crown were scorched. He also examined losses of diameter and height growth over a three year period (Figures 3 and 4). These data indicate that height growth is more severely affected than diameter growth in young pines. McCulley's findings appear to be conservative for plantations; others working with slash pine plantations have found less mortality and growth loss. Johansen (1975) reported no growth loss in a slash pine plantation when needle scorch was less than 40 percent. This is supported by Van Loon (1967) who found no long term growth loss, except in the most severe damage class, following a wildfire in a 6-1/2 year-old slash pine plantation.

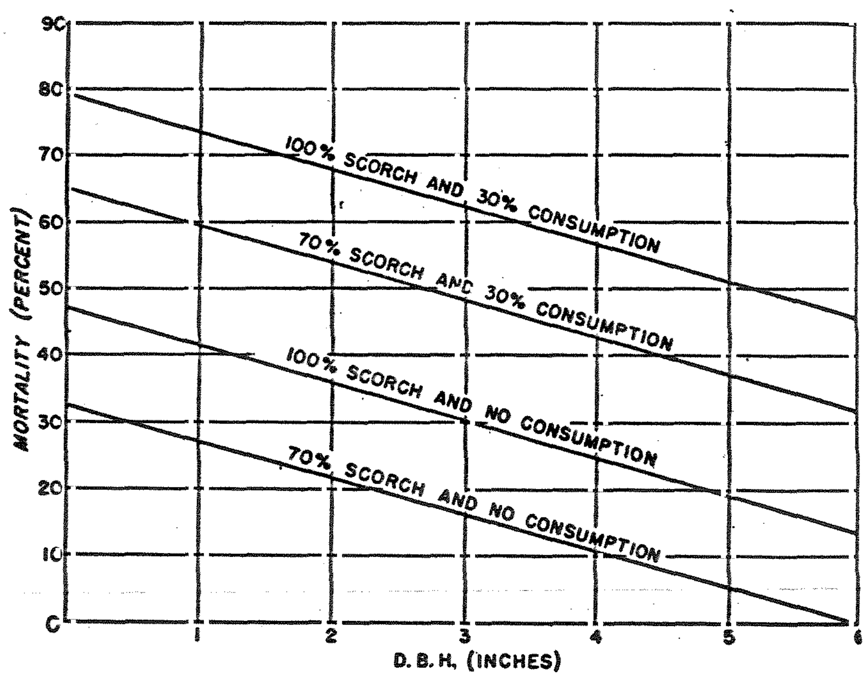

Figure 2.--Relationship of diameter, scorch, and needle consumption to post-fire mortality of slash pine (McCulley 1950).

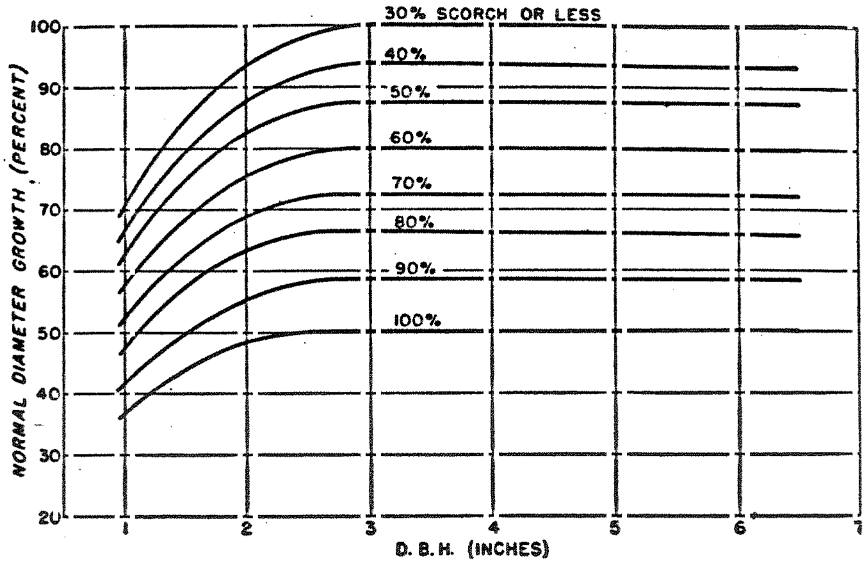

Figure 3.--Percent of normal diameter growth of slash pine, by diameter and scorch classes, for a 3-year period following prescribed fire (McCulley 1950).

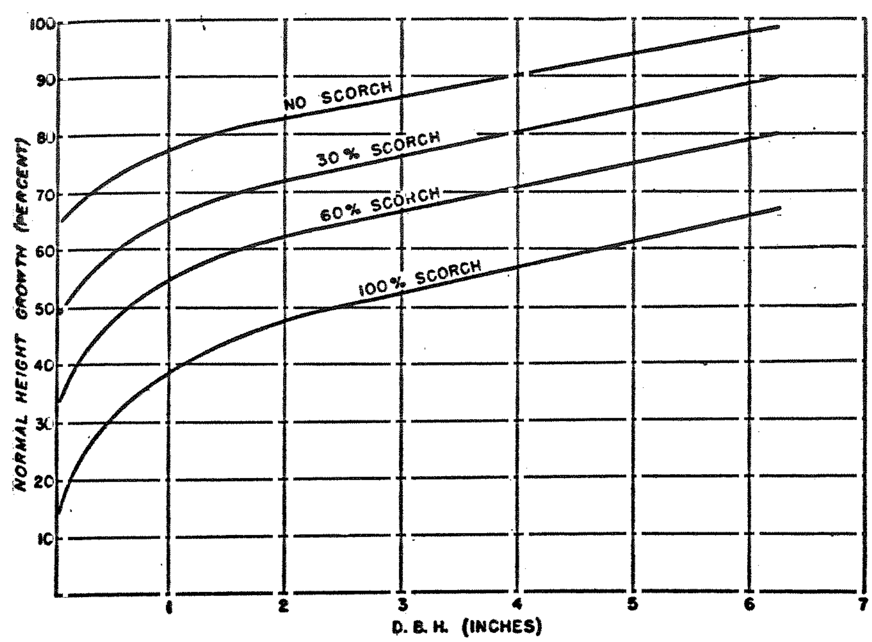

Figure 4.--Percent of normal height growth of slash pine, by diameter and scorch classes, for a 3-year period following prescribed fire (McCulley 1950).

Wade and Ward (1975) studied a slash pine plantation on a South Carolina sandhill site that suffered an intense, fast moving fire at age 5. Ambient air temperature was 86° F at the time of the fire and the burning index was at 100--the maximum. Initial stocking was 680 trees per acre and estimated SI_{25} was 50. One year later, more than 70 percent of the trees were living in spite of loss of terminal leaders on most trees and an invasion of pales weevil and tip moth. After seven years (age 12), there were 230 living trees/acre; of these 189 were healthy and expected to live, and 166 were in a vigor class that showed little or no damage. They concluded that young, healthy slash pine can withstand what appeared to be a disastrous fire and make a remarkable recovery, even with 100 percent crown scorch and dead terminal buds. As crown scorch dropped below 50 percent, mortality approached zero. Some factors that increase fire mortality are: high ambient temperatures; close spacing in plantations; trees in candle; and/or winds that are either erratic in direction or of very low speed, causing excessive heat build-up. Adverse weather conditions after the fire, such as prolonged drought or periods of abnormally high temperatures, can have a negative impact on stand recovery.

Thus when assessing fire damage to slash pine stands, use stem, crown, and/or cambium damage to estimate probable loss. Young stands (over 5 feet in height) have a surprising potential for recovery if little needle consumption occurred. Needle scorch of less than 40 percent of the crown may not cause a growth reduction (Johansen 1975). When crown consumption exceeds 30 percent in trees under 6" dbh, however, mortality will probably approach 50 percent. On young stands, check the number of surviving trees in the dominant and codominant classes to see if an adequate stand remains.

On older stands, the post-fire management choices might be: Immediate light salvage; cut to shelterwood and regenerate naturally; or clearcut and regenerate artificially. Unless the stand were over-mature or otherwise stressed, dominants and codominants likely would be the least affected. There is no one answer; each stand or tract will have to be evaluated on its own merits. Landowner objectives, stand age and condition, potential for losses to insects, and economic considerations will affect the choice. Miller and others (1961) reported that one company elected to harvest and regenerate immediately, because of its objective of maximizing productivity, and the potential for insect losses after partial harvesting, although the other two alternatives also appeared viable.

WEATHER

Snow, ice, and heat

Within its natural range, slash pine is infrequently damaged by ice storms. North of its natural range, however, damage can be both frequent and severe (Brender and Romancier 1965). McKellar (1942) reported that, as a result of a heavy glaze storm, 36 percent of slash pine trees in plantations 6 to 8 years old in the vicinity of Athens, Georgia, had broken limbs, and 50 percent were bent 45 degrees or more

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